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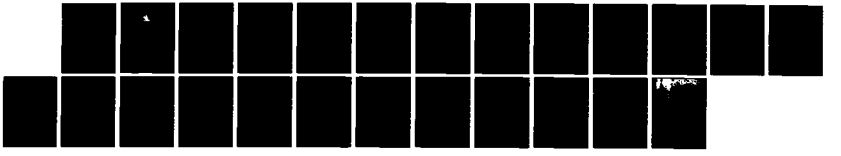

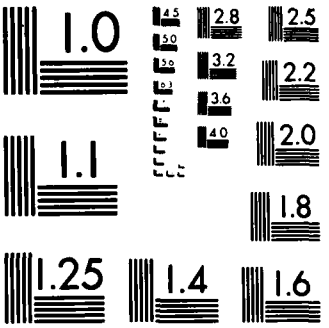

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CONTENTS

1. INTRODUCTION

The VERA reactor at AWRE has been used to study problems in the UK fast power reactor programme and in research reactor design. However, its main function has been to provide experimental results for small fast assemblies against which calculations can be compared to improve the nuclear cross-sections used. This report outlines the experimental methods used in the VERA work and gives the results.

This report was prepared in 1973 for internal use. However, it is the most up-to-data reference to data on the VERA critical masses, reaction rates and neutron spectra, and supersedes the interim data in reference (1). The data published by Paxton (2) were based on reference (1). The main changes concern the central reaction rate ratios which were re-measured using an improved technique and the neutron spectra which have not previously been published. This report is intended to assist those wishing to use the VERA cores as benchmark assemblies for integral data calculations.

2. THE VERA ASSEMBLIES USED

A full description of the design features of the VERA reactor has been published (3). The fuel and diluent materials used to build up the cores are in the form of plates 1/8 in. thick, 1.7 in. square. These are stacked with their planes horizontal inside vertically-mounted square steel tubes arranged in a close-fitting square array. Natural uranium is loaded above and below the core region in core elements, and throughout the lengths of elements surrounding the core region, to form a thick reflector all round the pseudo-cylindrical core.

Nuclear densities for the seven VERA cores used in the cross-section adjustment scheme are given in table 1. Four of them, 1B, 3A, 5A and 7A, are uranium-fuelled systems and the other three, 9A, 10A and 11A, are plutonium-fuelled systems. The cores consist of a large number of identical cell units each of which has one fuel plate with a few plates of diluent material. The plate arrangements in the unit cells of the seven cores are shown in figure 1. The composition includes a small amount of hydrogen present in the form of lacquer on the uranium and water vapour in the graphite.

The experimental work on these cores has included measurements of perturbation effects and neutron life-times, but only critical sizes, central reaction rate ratios and neutron spectra are used in the cross-section adjustment scheme.

3. CRITICAL SIZES

The critical mass for each experimental system is corrected first for control rod excess reactivity, counter holes and for edge irregularities to give the fuel mass of a smooth heterogeneous cylinder. The methods used for these corrections are straightforward and have been described elsewhere (3). More important are the conversions of heterogeneous cylinder masses to the values equivalent to cylindrical cores with homogeneous compositions. These conversions are based on measurements of reactivity changes produced by grouping the plates into pairs to form cells made from $\frac{1}{4}$ in. thick plates. The reactivities are then extrapolated to zero plate thickness using calculations to give the form

of the extrapolation. Two separate codes have been used for these calculations, SWAN (4) and MURAL (5). Both codes use collision probability methods to calculate the flux distributions through unit cells. Cell average cross-sections are derived from the flux distributions and used in critical size calculations with one-dimensional diffusion theory codes.

The adjustments to reactivities and critical masses of the standard 1/8 in. plate systems to give the homogeneous equivalent values are given in table 2, together with homogeneous cylinder and sphere masses. Some results differ from those published earlier (1) and quoted in Paxton's review (2). The conversions from cylindrical masses to equivalent sphere masses have been made using shape factors calculated for each assembly using the S_n transport codes TURTLE (6) and STRAINT (7). For cores 9A and 10A only critical size measurements were made and in each case the experimental error for the final reactivity is ± 0.9% sd. For the other five cores the conversions to homogeneous sphere reactivities are less uncertain and the experimental errors in reactivity are ± 0.2 to 0.5% sd.

4. CENTRAL REACTION RATE RATIOS

Fission rate ratios in VERA were originally measured (1) using chambers in core cavities, but these were subsequently found to be subject to systematic errors due to perturbing effects of the voids and chamber materials introduced. The reaction rates used in the cross-section adjustment scheme are for cores 1B, 3A, 5A and 11A and they have all been re-measured during 1971 using the recently improved foil activation methods. The foils are placed between the core plates and the disturbance to the structure is very small. The reactions used are fission rates in U-235, U-238 and Pu-239, capture in U-238 and U-238(n,2n).

For the fission rate measurements metal foils were irradiated at various positions within a cell at the core centre. The fission product gamma activity was measured above a threshold of 1.3 MeV using a pair of 2 in. sodium iodide scintillators on each side of the foil. Count rates obtained were calibrated in terms of absolute fission rates using a foil which had been subjected to a known number of fissions. This was done in a back-to-back fission chamber in a reactor core cavity, together with a thin deposit of known mass.

The U-238 capture measurements were made using coincidence counting of the gamma (106 keV) and X-ray (103 keV) from Np-239. The absolute efficiency of this counting has been determined by the Am-243 method described by Seufert and Stegemann (8).

The U-238(n,2n) measurements were made by counting coincidences between the 60 keV gamma-rays and the 96 keV X-rays arising from the decay of U-237. Foils irradiated in a known 14 MeV flux were used to derive the relationship between coincidence count rate and absolute reaction rate. Uncertainty in the published cross-section at 14 MeV, used in this calibration, is one of the main sources of experimental error in the results.

Reaction rates were measured at various positions within a central cell unit in both 1/8 in. plate and 1/4 in. plate pattern systems. Figure 2 shows results obtained in the 1/8 in. plate pattern cell in core 1B, together with distributions calculated using MURAL. In addition to measurements between the

plates, average rates in the fuel were obtained using rectangular foils fitted through the thickness of the plate. Cell average values of the reaction rates for 1/8 and 1/4 in. plate systems were derived by averaging the measured distributions. In table 3 the reaction rate results are shown expressed as cross-section ratios. Also shown are results of MURAL calculations used to extrapolate the measured ratios to the homogeneous equivalent values. Only for core 5A are appreciable changes made in these extrapolations and the greater uncertainty is the cause of larger experimental errors quoted for results in this core. The experimental errors for the fission rate ratios are 2 to 3% sd and these errors apply also to ratios of U-238 capture to U-235 fission for all but the core 5A result. The errors of about ± 12% for the U-238(n,2n)/U-238(n,f) ratios are due mainly to uncertainties in the 14 MeV calibrations and in the extrapolations to homogeneity for which no calculations were available.

5. NEUTRON SPECTRUM MEASUREMENTS

Neutron energy spectra have been measured at the centres of cores 1B, 3A, 5A, 7A and 11A between about 100 eV and 7 MeV. Four main methods have been used, pulsed source time-of-flight (9) in the energy range up to 100 keV, hydrogen-filled spherical proportional counters (10) between 10 keV and 1.5 MeV, nuclear emulsions (11) from 800 keV to 5 MeV, and a recently developed double scintillator time-of-flight method (12) in the range 250 keV to 14 MeV. Results for core 7A using the first three of these methods are shown in figure 3. The three sets of results are independently related to the flux scale shown without arbitrary normalisation in the regions of overlap. For the in-core methods this is done by monitoring the measurements with a U-235 fission counter placed alongside the spectrometer in the core cavity. For beam measurements it is necessary in addition to measure the ratio of the flux in the core cavity to that at the detector position in the beam. This ratio is energy-independent and can be measured with any detector sufficiently sensitive for beam measurements and small enough to fit into the core. We have used fission chambers but find hydrogen-filled proportional counters are more reliable.

By this means the methods check each other in regions of overlap. However, a long period of scanning (> 300 h) is needed to approach the required accuracy with nuclear emulsions and the overlap with proportional counter results is small. The double-scintillator time-of-flight spectrometer, shown in figure 4, was developed to give additional support to results above 200 keV. We have used this method on all five of the VERA assemblies mentioned above. An example of results, for core 7A, is given in figure 5, together with proportional counter and nuclear emulsion results. Also shown are results of measurements made on the same assembly at AERE, Harwell using a LINAC source for time-of-flight measurements with a 200 m flight path (13).

The double scintillator and pulsed source time-of-flight methods measure the spectrum of neutrons travelling parallel to the planes of the core plates, whereas the measurements made in core cavities are quite well averaged over all angles. The beam results have been converted to cell average spectra using MURAL, together with an associated code TOFFEE (14). TOFFEE includes a correction for the fact that a detector in the beam sees only a portion of the heterogeneous core structure through the collimators and the portion will not generally represent the average composition. Below 3 MeV the MURAL/TOFFEE corrections for the VERA measurements are less than 5%. However, at higher energies corrections up to 15% have been applied.

The results of spectrum measurements in cores 1B, 3A, 5A, 7A and 11A are given in tables 4, 5, 6, 7 and 8 respectively. The factors used to convert spectra measured in source-driven sub-critical systems to equivalent critical results were calculated using the source option of SWAN (4). MURAL (5) calculations have been used to convert the results for heterogeneous systems to the equivalent homogeneous spectra used in the cross-section adjustment scheme.

It should be noted that the nuclear densities in table 1 include the estimated quantity of hydrogen impurity in the graphite used in the assemblies. The spectra corresponding to these compositions are therefore the values in columns 5 divided by the factors in columns 2 for cores 1B, 3A and 11A. For cores 5A and 7A the hydrogen in the graphite has no significant effect on the spectra.

It is evident from compilations of measured cross-sections that estimated experimental errors are generally optimistic. It is particularly important that this should not apply to integral experiment results used in cross-section adjustment schemes. Where any doubt exists therefore we have tended to quote larger errors for the VERA results.

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TABLE 1

Composition of Cores of VERA Assemblies

Element or Isotope	Average Nuclear Density, nuclei/barn cm							
	Core No.	1B	3A	5A	7A	9A	10A	11A
U-235		0.007349	0.006186	0.006605	0.005676	-	-	-
U-238		0.000455	0.013255	0.000409	0.012154	-	-	-
U-234		0.000092	0.000076	0.000083	0.000071	-	-	-
U-236		0.000014	0.000011	0.000012	0.000011	-	-	-
Pu-239		-	-	-	-	0.010687	0.008632	0.007213
Pu-240		-	-	-	-	0.000544	0.000441	0.000370
Pu-241		-	-	-	-	0.000042	0.000034	0.000028
Ga		-	-	-	-	0.000668	0.000539	0.000449
Cu		-	-	-	-	0.010961	0.008858	0.007402
Pb		-	-	-	-	0.000053	0.000042	0.000035
Sn		-	-	-	-	0.000064	0.000051	0.000043
C		0.057540	0.035770	0.054610	0.035800	0.034215	0.041052	0.046204
H		0.000107	0.000178	0.006595	0.005775	0.000024	0.000029	0.000033
Fe		0.006283	0.006283	0.006283	0.006283	0.006094	0.006088	0.006084
Cr		0.001635	0.001635	0.001635	0.001635	0.001580	0.001579	0.001579
Ni		0.000689	0.000689	0.000689	0.000689	0.000665	0.000665	0.000665

TABLE 2

Homogenising Adjustments to Critical Masses

VERA Core No.	Reactivity Adjustment, %	Edge Mass Adjustment, kg of U-235 or Pu-239	Corrected Critical Mass, kg U-235 or Pu-239	
			Homogeneous Cylinder	Equivalent Sphere
1B	- 0.87 ± 0.05	3.61 ± 0.22	89.3 ± 0.4	84.2 ± 0.6
3A	- 1.09 ± 0.31	5.5 ± 1.6	110.4 ± 1.6	104.4 ± 1.7
5A	- 0.54 ± 0.15	1.24 ± 0.34	59.8 ± 0.4	56.9 ± 0.5
7A	- 0.26 ± 0.13	0.97 ± 0.49	76.5 ± 0.6	72.3 ± 0.7
9A	- 0.56 ± 0.14*	0.71 ± 0.17*	23.5 ± 0.6	22.6 ± 0.6
10A	- 0.68 ± 0.15*	0.85 ± 0.19*	28.8 ± 0.6	27.6 ± 0.6
11A	- 0.81 ± 0.14	1.01 ± 0.17	33.8 ± 0.4	32.4 ± 0.5

*Scaled from 11A values

TABLE 3

VERA Reaction Rate Ratios

Cell Average Cross-Section Ratio	Origin	Core Heterogeneity	VERA Core Number			
			1B	3A	5A	11A
$\frac{F8}{F5}$	Experiment	(standard	0.0833 ± 0.0018	0.0630 ± 0.0012	0.0564 ± 0.0016	0.102 ± 0.003
		(bunched	0.0794 ± 0.0019	-	0.0479 ± 0.0015	0.103 ± 0.001
	Calculation (MURAL)	(homog.	0.0740	0.0545	0.0565	0.0900
		(standard	0.0725	0.0545	0.0484	0.0897
		(bunched	-	-	0.0384	-
	Experimental equivalent	homog.	0.086 ± 0.002	0.0630 ± 0.0015	0.063 ± 0.002	0.102 ± 0.003
$\frac{F9}{F5}$	Experiment	(standard	1.189 ± 0.020	1.14 ± 0.02	1.256 ± 0.018	1.18 ± 0.02
		(bunched	1.177 ± 0.019	-	1.353 ± 0.020	1.19 ± 0.02
	Calculation (MURAL)	(homog.	1.140	1.129	1.135	1.173
		(standard	1.134	1.127	1.205	1.172
		(bunched	-	-	1.369	-
	Experimental equivalent	homog.	1.20 ± 0.02	1.14 ± 0.02	1.19 ± 0.03	1.18 ± 0.02
$\frac{C8}{F5}$	Experimental	(standard	0.137 ± 0.003	0.122 ± 0.002	0.33 ± 0.01	0.139 ± 0.004
		(bunched	0.139 ± 0.003	-	0.40 ± 0.02	-
	Calculation (MURAL)	(homog.	0.124	0.1209	0.198	0.1186
		(standard	0.126	0.1213	0.304	0.1192
		(bunched	-	-	0.367	-
	Experimental equivalent	homog.	0.135 ± 0.003	0.122 ± 0.002	0.22 ± 0.02	0.158 ± 0.004
$\frac{M8}{F8}$	Experiment	(standard	0.045 ± $\frac{0.002r}{0.004s}$	0.041 ± $\frac{0.002r}{0.004s}$	0.053 ± $\frac{0.003r}{0.005s}$	0.056 ± 0.006
		(bunched	0.039 ± $\frac{0.003r}{0.004s}$		0.047 ± $\frac{0.003r}{0.005s}$	-
	Experimental Equivalent	homog.	0.048 ± 0.006	0.041 ± 0.005	0.056 ± 0.007	0.056 ± 0.007

(r = random)
(s = systematic)

TABLE 4

Core 1B Neutron Spectrum

32 Set Group No.	Upper Energy	(1) Cell Average Flux Per Unit Lethargy $\phi(u)$	(2) Conversion Factors to Zero Hydrogen in Graphite	(3) Conversion Factors Critical / Source Driven Sub-Critical	(4) Conversion Factors Homogeneous / Heterogeneous	(5) $\phi(u)$ for Critical Homogeneous Assembly with no H in Graphite
6	8 MeV	6.7 ± 2.0	1.00	0.88	1.00	6.0 ± 1.8
7	6.5	10.5 ± 2.0	1.00	1.00	1.00	10.5 ± 2.0
8	5.0	20.0 ± 1.5	1.00	1.00	1.00	20.0 ± 1.5
9	3.4	35.0 ± 2.5	1.00	1.01	1.00	35.5 ± 2.5
10	2.4	48.5 ± 3.0	1.00	1.02	1.00	49.5 ± 3.0
11	1.6	53.5 ± 3.0	1.00	1.01	1.00	54.0 ± 3.0
12	1.1	52.0 ± 2.5	1.00	1.01	1.00	52.5 ± 2.5
13	0.78	54.0 ± 3.0	1.00	1.00	1.00	54.0 ± 3.0
14	0.55	53.0 ± 3.0	1.00	1.00	1.00	53.0 ± 3.0
15	0.37	50.5 ± 2.5	1.00	1.00	1.00	50.5 ± 2.5
16	0.26	45.0 ± 2.5	1.00	0.99	1.00	44.5 ± 2.5
17	0.18	41.0 ± 2.5	1.00	0.99	1.00	40.5 ± 2.5
18	0.13	33.5 ± 2.0	1.00	0.98	1.00	33.0 ± 2.0
19	80 keV	25.5 ± 2.0	1.00	0.97	1.00	24.5 ± 2.0
20	43	17.3 ± 1.5	1.00	0.97	1.00	17.0 ± 1.5
21	22	11.8 ± 1.0	1.00	0.97	0.99	11.3 ± 1.0
22	10	6.1 ± 0.6	0.99	0.98	0.96	5.7 ± 0.6
23	4	2.7 ± 0.3	0.97	0.99	0.91	2.4 ± 0.3
24	1.6	0.95 ± 0.15	0.93	1.00	0.82	0.72 ± 0.12
25	0.65	0.26 ± 0.05	0.87	1.00	0.68	0.15 ± 0.04
26	0.26					

Estimated systematic errors are the largest parts of the quoted uncertainties which should be taken as 1 sd. Where these exceed 1.2 in column 5 the fluxes are rounded to the nearest 0.5.

TABLE 5

Core 3A Neutron Spectrum

32 Set Group No.	Upper Energy	(1) Cell Average Flux Per Unit Lethargy $\phi(u)$	(2) Conversion Factors to Zero Hydrogen in Graphite	(3) Conversion Factors Critical / Source Driven Sub-Critical	(4) Conversion Factors Homogeneous / Heterogeneous	(5) $\phi(u)$ for Critical Homogeneous Assembly with no H in Graphite
6	8 MeV	4.5 ± 2.0	1.00	0.95	1.00	4.5 ± 2.0
7	6.5	7.5 ± 2.0	1.00	1.00	1.00	7.5 ± 2.0
8	5.0	15.5 ± 1.5	1.00	1.01	1.00	15.5 ± 1.5
9	3.4	26.5 ± 1.5	1.00	1.01	1.00	27.0 ± 1.5
10	2.4	40.0 ± 2.0	1.00	1.01	1.00	40.5 ± 2.0
11	1.6	44.5 ± 2.0	1.00	0.99	1.00	44.0 ± 2.0
12	1.1	52.0 ± 2.5	1.00	1.00	1.00	52.0 ± 2.5
13	0.78	61.0 ± 3.0	1.00	1.00	1.00	61.0 ± 3.0
14	0.55	65.0 ± 3.0	1.00	1.00	1.00	65.0 ± 3.0
15	0.37	63.5 ± 3.0	1.00	1.00	1.00	63.5 ± 3.0
16	0.26	57.0 ± 3.0	1.00	1.00	1.00	57.0 ± 3.0
17	0.18	50.0 ± 3.0	1.00	1.00	1.00	50.0 ± 3.0
18	0.13	40.0 ± 2.5	1.00	1.00	1.00	40.0 ± 2.5
19	80 keV	27.5 ± 2.0	1.00	1.00	1.00	27.5 ± 2.0
20	43	17.5 ± 1.5	1.00	1.00	1.00	17.5 ± 1.5
21	22	10.4 ± 1.0	0.99	1.00	0.99	10.2 ± 1.0
22	10	4.6 ± 0.5	0.98	1.00	0.96	4.3 ± 0.5
23	4	1.85 ± 0.20	0.96	1.01	0.88	1.58 ± 0.19
24	1.6	0.64 ± 0.10	0.92	1.01	0.75	0.45 ± 0.08
25	0.65	0.16 ± 0.03	0.87	1.01	0.54	0.08 ± 0.03
26	0.26					

Estimated systematic errors are the largest parts of the quoted uncertainties which should be taken as 1 sd. Where these exceed 1.2 in column 5 the fluxes are rounded to the nearest 0.5.

TABLE 6

Core 5A Neutron Spectrum

32 Set Group No.	Upper Energy	(1) Cell Average Flux per Unit Lethargy $\phi(u)$	(3) Conversion Factors Critical Source Driven Sub-Critical	(4) Conversion Factors Homogeneous Heterogeneous	(5) $\phi(u)$ for Critical Homogeneous Assembly
7	6.5 MeV	7.0 ± 2.0	1.00	1.00	7.0 ± 2.0
8	5.0	13.0 ± 2.0	1.00	1.00	13.0 ± 2.0
9	3.4	21.5 ± 2.0	1.00	1.00	21.5 ± 2.0
10	2.4	30.5 ± 1.7	1.01	1.00	31.0 ± 1.7
11	1.6	30.5 ± 1.5	1.01	1.00	31.0 ± 1.5
12	1.1	31.5 ± 1.5	1.01	1.00	32.0 ± 1.5
13	0.78	30.5 ± 1.7	1.01	1.00	31.0 ± 1.7
14	0.55	28.5 ± 1.5	1.00	1.00	28.5 ± 1.5
15	0.37	26.0 ± 1.5	1.00	1.00	26.0 ± 1.5
16	0.26	22.2 ± 1.3	1.00	1.00	22.2 ± 1.3
17	0.18	19.7 ± 1.2	1.00	1.00	19.7 ± 1.2
18	0.13	17.0 ± 1.2	1.00	1.00	17.0 ± 1.2
19	80 keV	12.3 ± 0.9	0.99	1.00	12.2 ± 0.9
20	43	8.6 ± 0.8	0.99	1.00	8.5 ± 0.8
21	22	6.6 ± 0.7	0.99	1.00	6.5 ± 0.7
22	10	5.0 ± 0.5	0.99	1.00	5.0 ± 0.5
23	4	4.05 ± 0.40	0.99	0.99	3.95 ± 0.40
24	1.6	2.90 ± 0.30	0.99	0.96	2.75 ± 0.30
25	0.65	1.88 ± 0.19	0.99	0.88	1.64 ± 0.17
26	0.26	1.33 ± 0.14	0.99	0.79	1.04 ± 0.12
27	0.11				

Estimated systematic errors are the largest parts of the quoted uncertainties which should be taken as 1 sd. Where these exceed 1.2 in column 5 the fluxes are rounded to the nearest 0.5

TABLE 7

Core 7A Neutron Spectrum

32 Set Group No.	Upper Energy	(1) Cell Average Flux per Unit Lethargy $\phi(u)$	(3) Conversion Factors Critical Source Driven Sub-Critical	(4) Conversion Factors Homogeneous Heterogeneous	(5) $\phi(u)$ for Critical Homogeneous Assembly
7	6.5 MeV	6.2 ± 1.0	1.02	1.00	6.3 ± 1.0
8	5.0	13.5 ± 2.0	1.02	1.00	14.0 ± 2.0
9	3.4	19.0 ± 1.5	1.03	1.00	19.5 ± 1.5
10	2.4	24.0 ± 2.0	1.03	1.00	24.5 ± 2.0
11	1.6	27.5 ± 2.0	0.99	1.00	27.0 ± 2.0
12	1.1	32.0 ± 2.0	1.01	1.00	32.5 ± 2.0
13	0.78	35.5 ± 2.0	1.01	1.00	36.0 ± 2.0
14	0.55	35.0 ± 2.0	1.01	1.00	35.5 ± 2.0
15	0.37	32.5 ± 2.0	1.01	1.00	33.0 ± 2.0
16	0.26	28.5 ± 2.0	1.00	1.00	28.5 ± 2.0
17	0.18	25.0 ± 1.5	1.00	1.00	25.0 ± 1.5
18	0.13	20.0 ± 1.2	1.00	1.00	20.0 ± 1.2
19	80 keV	15.0 ± 1.0	0.99	1.01	15.0 ± 1.0
20	43	10.5 ± 0.8	0.99	1.01	10.5 ± 0.8
21	22	7.9 ± 0.7	0.99	1.01	7.9 ± 0.7
22	10	5.5 ± 0.5	0.99	1.01	5.5 ± 0.5
23	4	4.2 ± 0.4	0.99	0.98	4.1 ± 0.4
24	1.6	3.0 ± 0.3	0.99	0.93	2.8 ± 0.3
25	0.65	1.9 ± 0.2	0.99	0.86	1.6 ± 0.2
26	0.26	1.28 ± 0.12	0.99	0.75	0.95 ± 0.10
27	0.11				

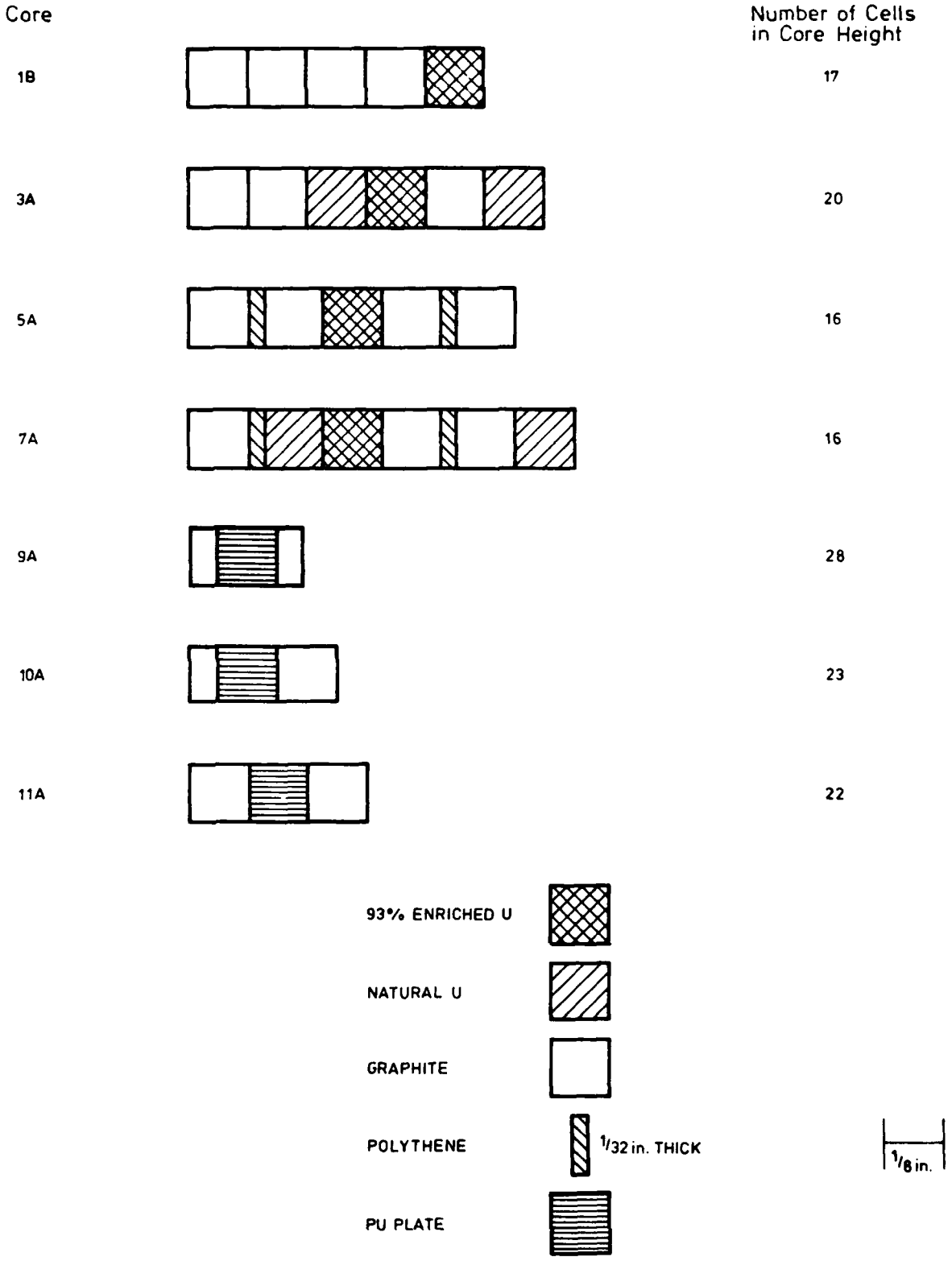
Estimated systematic errors are the largest parts of the quoted uncertainties which should be taken as 1 sd. Where these exceed 1.2 in column 5 the fluxes are rounded to the nearest 0.5.

TABLE 8

Core 11A Neutron Spectrum

32 Set Group No.	Upper Energy	(1) Cell Average Flux per Unit Lethargy $\phi(u)$	(2) Conversion Factors to Zero Hydrogen in Graphite	(3) Conversion Factors Critical Source Driven Sub-Critical	(4) Conversion Factors Homogeneous Heterogeneous	(5) $\phi(u)$ for Critical Homogeneous Assembly with no H in Graphite
6	8 MeV	2.5 ± 1.0	1.00	1.00	1.00	2.5 ± 1.0
7	6.5	7.8 ± 1.0	1.00	1.00	1.00	7.8 ± 1.0
8	5.0	21.0 ± 2.5	1.00	1.00	1.00	21.0 ± 2.5
9	3.4	35.0 ± 3.5	1.00	1.00	1.00	35.0 ± 3.5
10	2.4	51.5 ± 3.5	1.00	1.00	1.00	51.5 ± 3.5
11	1.6	52.5 ± 3.0	1.00	1.00	1.00	52.5 ± 3.0
12	1.1	53.0 ± 3.0	1.00	1.00	1.00	53.0 ± 3.0
13	0.78	53.0 ± 3.0	1.00	1.00	1.00	53.0 ± 3.0
14	0.55	49.0 ± 2.5	1.00	1.00	1.00	49.0 ± 2.5
15	0.37	44.0 ± 2.5	1.00	1.00	1.00	44.0 ± 2.5
16	0.26	39.0 ± 2.5	1.00	1.00	1.00	39.0 ± 2.5
17	0.18	36.0 ± 2.0	1.00	1.00	1.00	36.0 ± 2.0
18	0.13	28.5 ± 1.7	1.00	1.00	1.00	28.5 ± 1.7
19	80 keV	21.5 ± 1.5	1.00	0.98	1.00	21.0 ± 1.5
20	43	14.0 ± 1.2	1.00	0.98	1.00	13.5 ± 1.2
21	22	9.0 ± 0.9	1.00	0.99	1.00	8.9 ± 0.9
22	10	4.6 ± 0.5	0.99	1.00	1.00	4.6 ± 0.5
23	4	2.15 ± 0.25	0.97	1.01	0.96	2.00 ± 0.24
24	1.6	0.85 ± 0.10	0.94	1.03	0.94	0.77 ± 0.09
25	0.65	0.25 ± 0.05	0.91	1.04	0.82	0.19 ± 0.04
26	0.26					

Estimated systematic errors are the largest parts of the quoted uncertainties which should be taken as 1 sd. Where these exceed 1.2 in column 5 the fluxes are rounded to the nearest 0.5.



A DESCRIPTION OF THE CORE CONSTRUCTION AND THE MATERIAL PLATES IS GIVEN IN REFERENCE (3), VOL 1 pp 159 - 195

FIGURE 1 Plate Patterns in Unit Cells

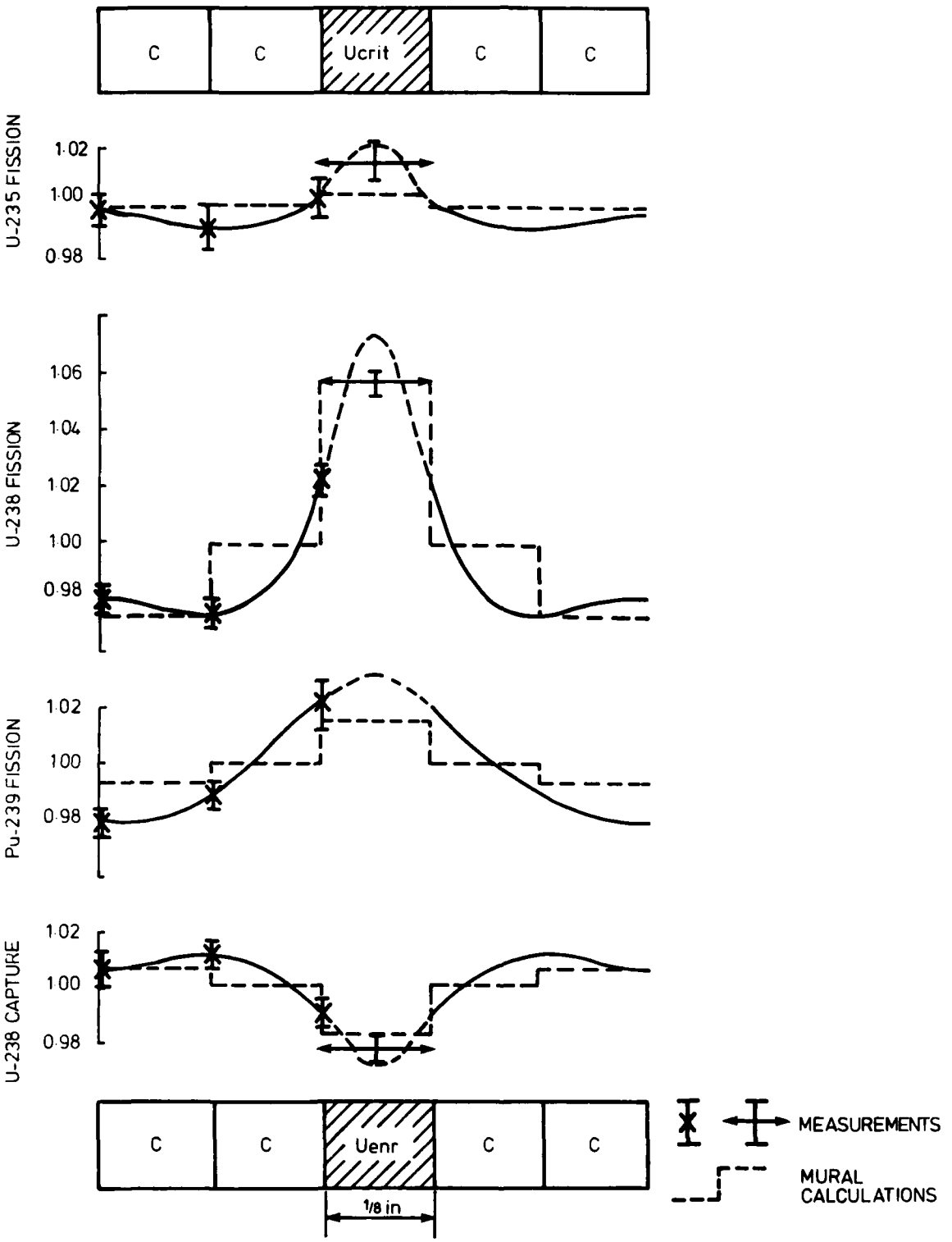


FIGURE 2 Reaction Rate Distributions, Core 1B

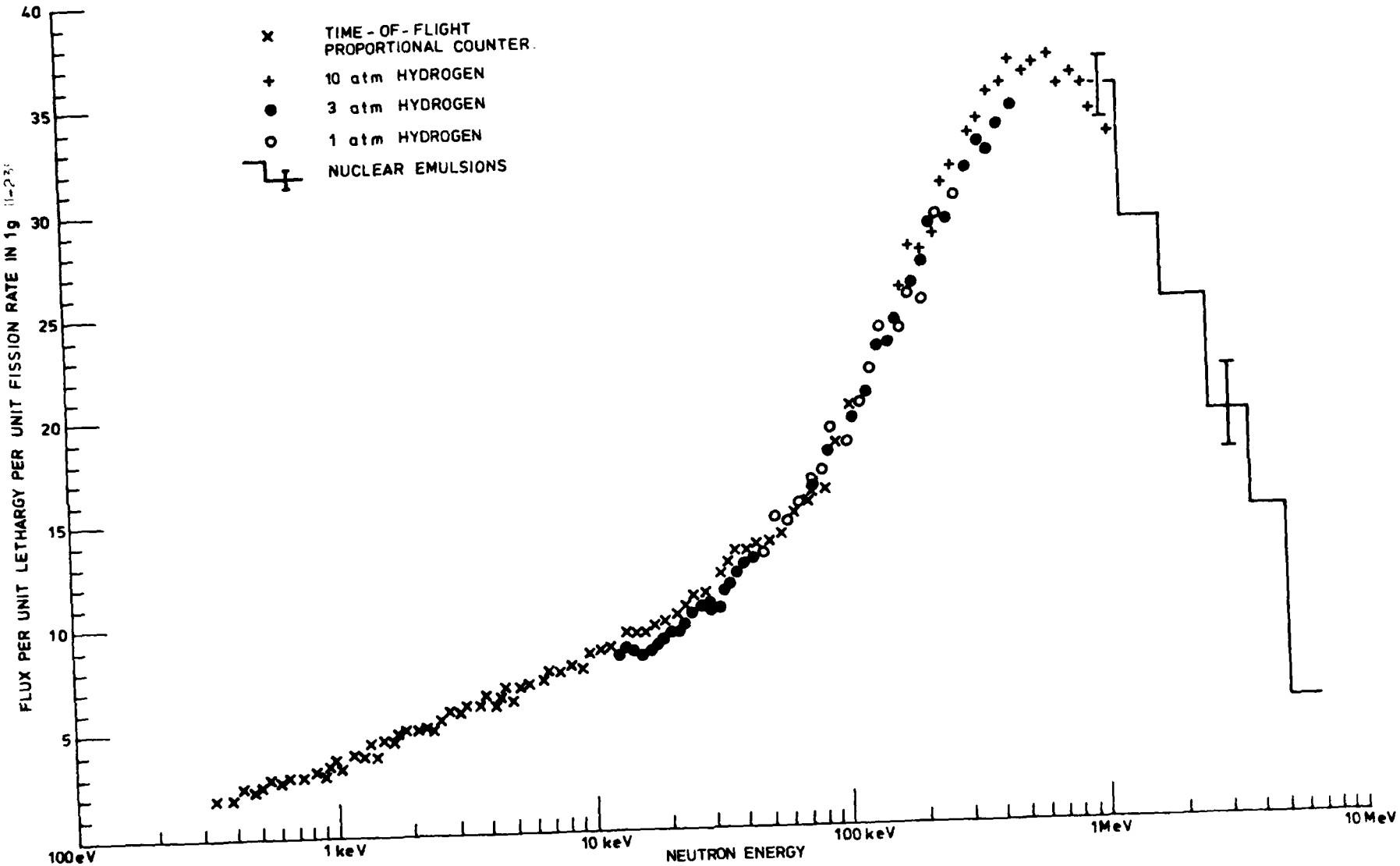


FIGURE 3. Vera 7A. Neutron Spectrum Measurements.

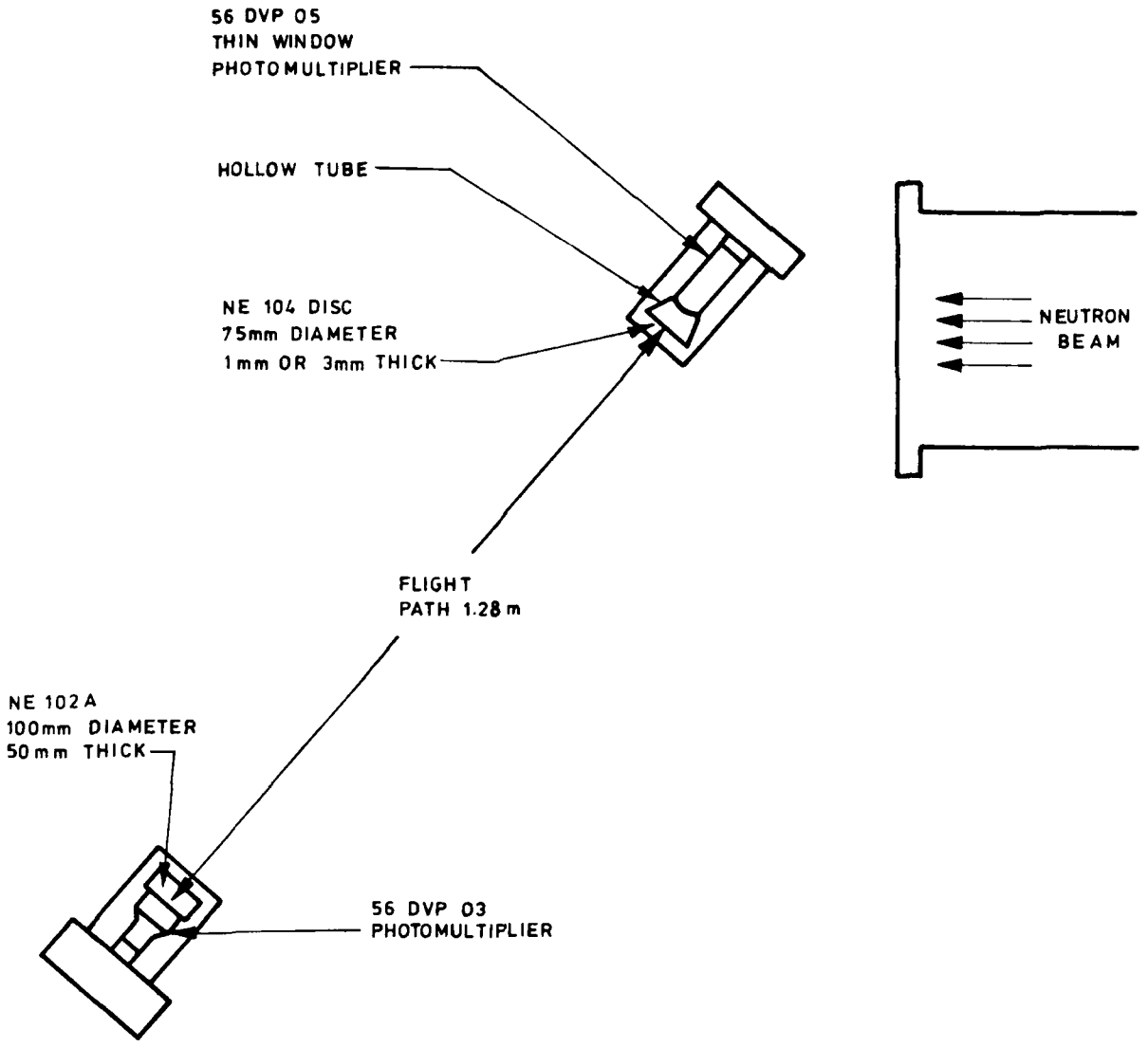


FIGURE 4 Double Scintillator Spectrometer

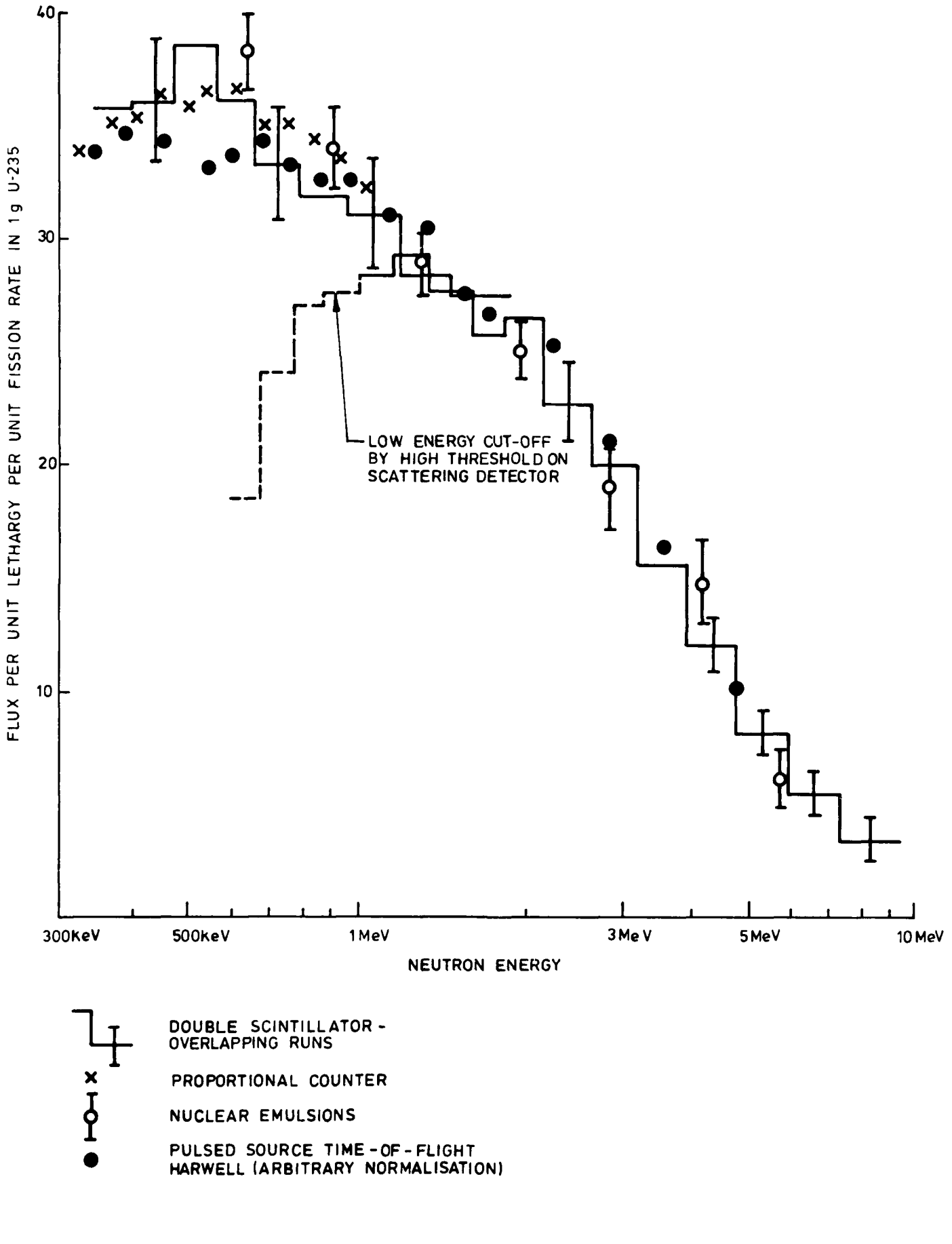


FIGURE 5 Spectrum Measurements, Core 7A

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1. DRIC Reference (if known)	2. Originator's Reference	3. Agency Reference	4. Report Security Classification
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-	Atomic Weapons Research Establishment, Aldermaston, Berkshire

5a. Sponsoring Agency's Code (if known)	6a. Sponsoring Agency (Contract Authority) Name and Location
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7. Title

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7a. Title in Foreign Language (in the case of Translation)

-

7b. Presented at (for Conference Papers). Title, Place and Date of Conference

-

8. Author 1.Surname, Initials	9a. Author 2	9b. Authors 3, 4	10. Date	pp	ref
Paterson W J	-	-	June 1983	21	13

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Abstract

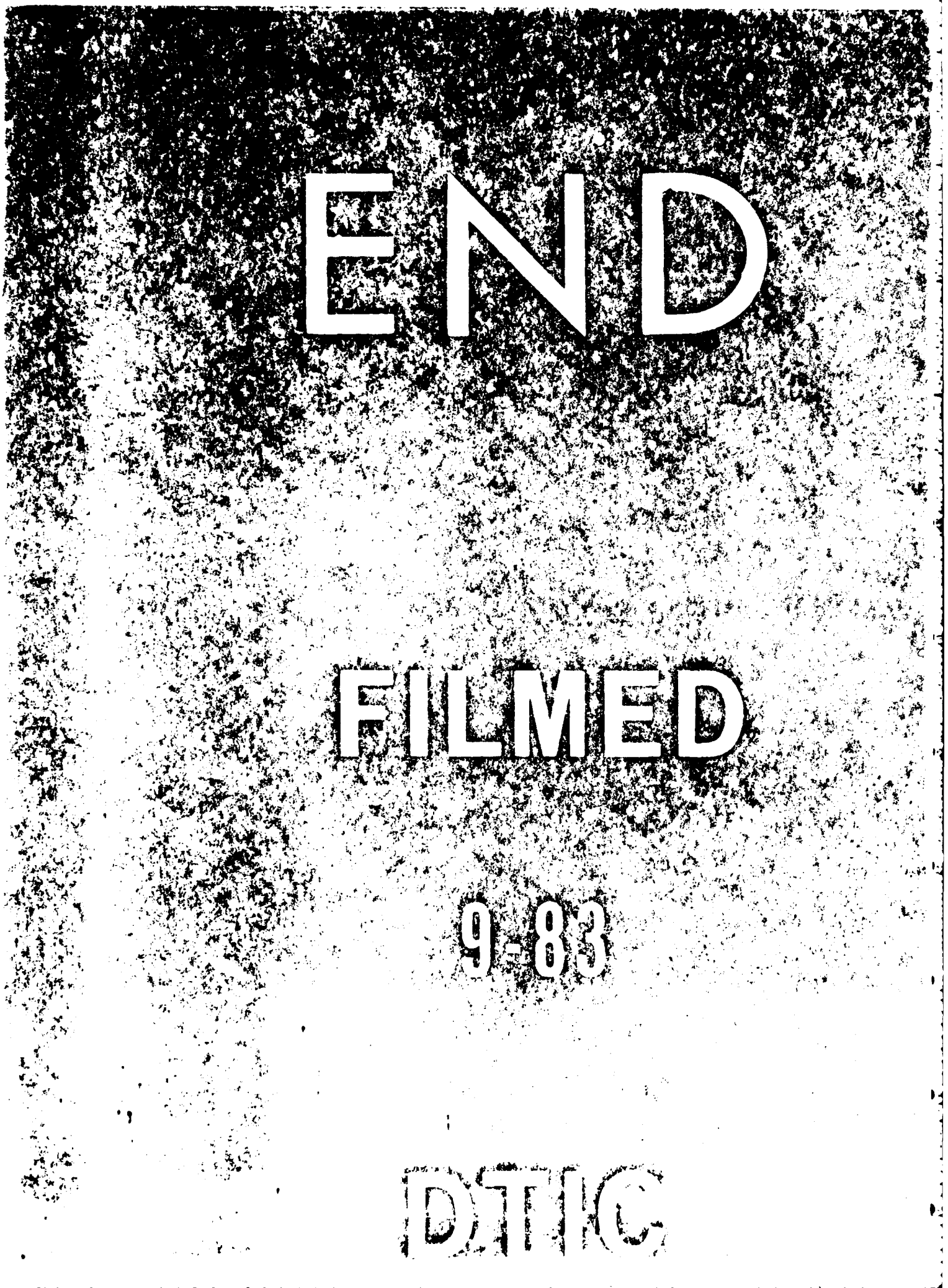
The VERA reactor at AWRE has been used to study problems in the UK fast power reactor programme and in research reactor design. However, its main function has been to provide experimental results for small fast assemblies against which calculations can be compared to improve the nuclear cross-sections used. This report outlines the experimental methods used in the VERA work and gives the results.

Some Metric and SI Unit Conversion Factors

(Based on DEF STAN 00-11/2 "Metric Units for Use by the Ministry of Defence", DS Met 5501 "AWRE Metric Guide" and other British Standards)

Quantity	Unit	Symbol	Conversion
Basic Units			
Length	metre	m	1 m = 3.2808 ft 1 ft = 0.3048 m
Mass	kilogram	kg	1 kg = 2.2046 lb 1 lb = 0.45359237 kg 1 ton = 1016.05 kg
Derived Units			
Force	newton	$N = kg\ m/s^2$	1 N = 0.2248 lbf 1 lbf = 4.44822 N
Work, Energy, Quantity of Heat	joule	J = N m	1 J = 0.737562 ft lbf 1 J = 9.47817×10^{-4} Btu 1 J = 2.38846×10^{-4} kcal 1 ft lbf = 1.35582 J 1 Btu = 1055.06 J 1 kcal = 4186.8 J
Power	watt	W = J/s	1 W = 0.238846 cal/s 1 cal/s = 4.1868 W
Electric Charge	coulomb	C = A s	-
Electric Potential	volt	V = W/A = J/C	-
Electrical Capacitance	farad	F = A s/V = C/V	-
Electric Resistance	ohm	Ω = V/A	-
Conductance	siemen	$S = 1\ \Omega^{-1}$	-
Magnetic Flux	weber	Wb = V s	-
Magnetic Flux Density	tesla	$T = Wb/m^2$	-
Inductance	henry	H = V s/A = Wb/A	-
Complex Derived Units			
Angular Velocity	radian per second	rad/s	1 rad/s = 0.159155 rev/s 1 rev/s = 6.28319 rad/s
Acceleration	metre per square second	m/s^2	1 m/s^2 = 3.28084 ft/s^2 1 ft/s^2 = 0.3048 m/s^2
Angular Acceleration	radian per square second	rad/s^2	-
Pressure	newton per square metre	N/m^2 = Pa	1 N/m^2 = 145.038×10^{-6} lbf/in^2 1 lbf/in^2 = 6.89476×10^3 N/m^2
	bar	bar = 10^5 N/m^2	- 1 in. Hg = 3386.39 N/m^2
Torque	newton metre	N m	1 N m = 0.737562 lbf ft 1 lbf ft = 1.35582 N m
Surface Tension	newton per metre	N/m	1 N/m = 0.0685 lbf/ft 1 lbf/ft = 14.5939 N/m
Dynamic Viscosity	newton second per square metre	$N\ s/m^2$	1 $N\ s/m^2$ = 0.0208854 $lbf\ s/ft^2$ 1 $lbf\ s/ft^2$ = 47.8803 $N\ s/m^2$
Kinematic Viscosity	square metre per second	m^2/s	1 m^2/s = 10.7639 ft^2/s 1 ft^2/s = 0.0929 m^2/s
Thermal Conductivity	watt per metre kelvin	W/m K	-
Odd Units*			
Radioactivity	becquerel	Bq	1 Bq = 2.7027×10^{-11} Ci 1 Ci = 3.700×10^{10} Bq
Absorbed Dose	gray	Gy	1 Gy = 100 rad 1 rad = 0.01 Gy
Dose Equivalent	sievert	Sv	1 Sv = 100 rem 1 rem = 0.01 Sv
Exposure	coulomb per kilogram	C/kg	1 C/kg = 3876 R 1 R = 2.58×10^{-4} C/kg
Rate of Leak (Vacuum Systems)	millibar litre per second	mb l/s	1 mb = 0.750062 torr 1 torr = 1.33322 mb

*These terms are recognised terms within the metric system.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